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Case report

Fatal attack by a juvenile tiger shark, *Galeocerdo cuvier*, on a kitesurfer in New Caledonia (South Pacific)

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ABSTRACT

We present a case of a non-provoked fatal shark attack on a 15-year old male kitesurfer in New Caledonia. The victim lost his board and was pulled by the sail along the water surface in a reef passage when a shark attacked. The shark inflicted at least two bites on the left leg, including a severe one around the knee, resulting in a quick hypovolemic shock that was fatal. The analysis of one of these bites indicated that a 2.8 m TL (est. length) tiger shark was responsible for this attack. The features of the attack are consistent with those of a predator response to a surface feeding stimulus.

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1. Introduction

Seven fatalities resulted from unprovoked shark attacks worldwide in 2012, less than the 2011 total of 12, but above the 2001–2010 yearly average of 4.4.[8] This slight increase in shark attacks during the past two years, compared with the average of the last decade, is consistent with an increased number of people in the water.[22] It creates however a strong concern and irrational fear amongst recreational sea users and remains an unresolved puzzle for coastal managers, scientists, policymakers, and conservationists, who attempt to balance the protection of endangered predatory marine animals against potentially serious physical harm to humans.[13]

A better understanding of shark motivations and behavior through forensic analysis should at least partly help to avoid adverse outcomes in human encounters with these endangered creatures.[2,16] If there is a witness to an attack, comparison of display features between the different species of potentially dangerous sharks can help in defining implications for shark–human interactions and suggest responses which may decrease the likelihood of attack for swimmers or divers faced with a displaying shark.[12] After the attack, the bite structure of the wounds may reflect the motivation and behavior of the shark.[17]

The three main species involved in fatal attacks around the world are the white shark, *Carcharodon carcharias*, the tiger shark, *Galeocerdo cuvier*, and the bullshark, *Carcharinhus leucas*.[8] The first two of these are known migratory species, while the bull shark is also known to be migratory, but also spends substantial time in a localized area, including in New Caledonia, South Pacific.[21] The reliable identification of the species responsible for an attack may have critical consequences in identifying more risky periods of the year, once the local behavior and ecology of these large predators is better known.[4] For example still in New Caledonia, the two fatal attacks that occurred in 2007 and 2009 were scientifically analyzed and it was concluded that the species involved in both attacks was a white shark, consistent with the seasonal occurrence in New Caledonian waters of this migratory species.[3,5]

Here we describe the case of a young male kitesurfer who was fatally attacked in March 2011 by a shark in a reef passage off Koumac, North Western coast of New Caledonia (South Pacific). The information provided by the witnesses and the forensic analysis of the attack has allowed us to accurately determine the species involved and propose an hypothesis defining the features of the attack.

2. Description of the case

On 21 May 2011, a 15-year old male was kitesurfing in a group of five in a reef passage, between the lagoon and the open ocean (S 20°67′80 and E 164°25′46), off the city of Koumac on the northwest

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coast of New Caledonia. The water was clear and its temperature was around 26 °C, with a 15–20 kt SE wind. After a kitesurfing session lasting around 45 min the victim lost his board but was still holding his sail and pulled at the surface, trying to reach his board, when he suddenly shouted that he had been bitten by a shark. The victim kept holding the sail, apparently trying to escape towards a small islet at the rear of the reef passage. He collapsed and was held up by one of the teenagers in the group until the two adults from the group – the victim's father and a medical doctor – reached the victim and applied CPR without success. Following transfer of the body to hospital in Koumac a brief autopsy was conducted. The body was later moved to the capital city Noumea and a more detailed autopsy was conducted on 23 May by one of the authors (JMB). We used all this information in the analysis.

On the basis of the body examination and the witnesses' statements, it was evident that the shark approached the victim from below. The major wound (W1: 38 cm in length) with a significant loss of tissue was centered on both sides of the knee in the front and internal sides of the leg (Fig. 1(a)). Two other smaller wounds, with almost no loss of tissue, were inflicted on the back of the leg : one at the level of the thigh (W2: 18 cm in length and 10 cm in width), another one behind the knee and the top of the calf (W3 : 30 cm in length and 7 cm in width) (Fig. 1(b)). As mentioned in the autopsy report, the death was undoubtedly provoked by a cardio-pulmonary collapse due to the huge hemorrhage following the cut of the left femoral blood vessel through the first wound.

To conduct the analysis of the wounds, we mainly used the methodology described by Lowry et al.,[11] based on the use of the 'Inter Dental Distance' (IDD) and the 'bite Circumference' (BC) for assessing the species and size of the shark. The analysis of the pattern of the teeth marks, directly linked to the species-specific teeth characteristics of the shark, were also compared with dental impressions of the three main candidate species (Fig. 2). Rapid-curing vinyl polysiloxane impression material putty was used to make these impressions using dried jaws from sharks of accurately measured total length collected from the NSW Shark Meshing Program.[15] Our knowledge and expertise in shark ecology and attacks were also relevant for finalizing conclusions about the case.

The analysis of the first wound (W1) revealed that it was probably the result of two different adjacent and overlapping bites (B1 and B2), or one single bite inflicted as the leg was bending (Fig. 3(a)). Analysis of the lower bite B2 showed that the orientation of the tooth impressions and their shape, particularly the small, smoothly sliced flaps (see details in Fig. 3(b) and (b′)), together with the very smooth arc of the upper jaw bite, indicate a tiger shark as responsible for this attack. This hypothesis is confirmed by the observation of the three first teeth impressions from the bottom

Fig. 2. Teeth impressions from the lower jaw of the three main candidate species of shark, potentially involved in the fatal attack : (a) tiger shark, *Galeocerdo cuvier*; (b) bullshark, *Carcharhinus leucas*, and (c) white shark, *Carcharodon carcharias*. The teeth impressions of tiger shark are long and thin, very close to each other, sometimes almost overlapping. Teeth impressions of bullshark and white shark are more «needle-like» and separated, leading to much higher Inter-Dental Distances (IDD) for a given size of shark.

left of the bite corresponding to the third wound (W3). These impressions are more or less parallel, and have sharp cut corners, which is also consistent with a tiger shark (see arrows 1, 2 and 3 below W3 in Fig. 1(b)). Finally, the shape of the tooth impressions show no clear morphological differences between those from the upper and lower jaws, indicating dignathic homodont jaws,[7(p30)] characteristic of the tiger shark, compared to the white shark and bullshark which have dignathic heterodont jaws.

The IDD measurements for the lower jaw impression of B2 ranged from 17 mm to 20 mm, with an average of 18 mm (Fig. 3(b′)). Based on Lowry et al.,[11] an average IDD of 18 mm corresponds to a tiger shark of 2.73 m Total Length (TL). Given the absence of loss of tissue in the second and third wounds (W2 and W3), we concluded that they were partial and unfinished bites, potentially inflicted at the same time by the two hemi-jaws of the shark (either the upper or lower jaw). This hypothesis seems to be confirmed by the presence of two superficial scratches between the two wounds which were inflicted by the symphyseal teeths (at the juncture of the two hemi-jaws) (see Fig. 4 and arrows 4 and 5 between W2 and W3 in Fig. 1(b)). This would indicate W1 being the result of a single bite on a bending leg. If so, the bite circumference could be assessed as approx. 38 cm. In such a case and based on

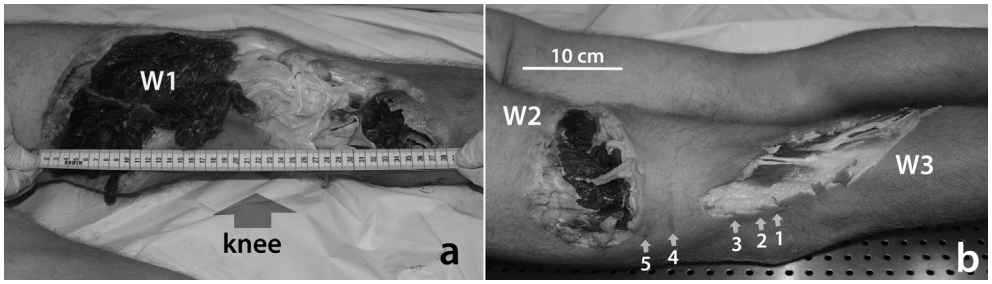

Fig. 1. Lateral (a) and dorsal (b) views of the left leg of the 15-year old victim. (a) The first wound (W1) is 38 cm long (with an average 10 cm of width) and is centered on the knee, covering the internal and front sides of the leg. The bottom of W1 starts 32 cm from the bottom of the foot. (b) The second wound has a quasi-circular frame with a length of 16 cm and a width of 10 cm. The third wound (W3) has an elongated frame with length 30 cm width 7 cm. Arrows 1, 2 and 3 show the specific parts of the wound with sharp and square corners, quasi parallel cuts, that are characteristic of a tiger shark teeth impressions. Arrows 4 and 5 indicate two superficial scratches inflicted by two symphyseal teeth (at the junction of the two jaw segments).

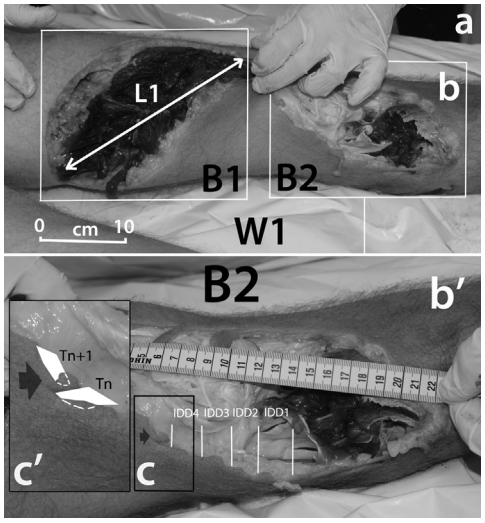

Fig. 3. (a) General view of the first wound (W1) which clearly shows two parts of equal size (B1 and B2). The lower part of W1 (B2) is 23 cm long (b), such as the top part of W1 (B1) which is also 23 cm long (L1). We hypothesize that it is a single bite inflicted on a bending leg, with the middle of the jaws centered on the knee. (b') Close up view on (b): the lower and left part of the bite allowed the calculation of an average IDD (18 mm) based on four adjacent teeth impressions determining IDD1 (20 mm), IDD2 (17 mm), IDD3 (18 mm) and IDD4 (18 mm). (c') Close up view of (c) showing a skin flap which results from two overlapping teeth (Tn and Tn+1), indicated by the arrow. This type of flap is specific of overlapping teeth impressions, such as for the tiger shark (see Fig. 2).

Lowry et al.,[11] the size of the shark would be 2.82 m TL. Using both IDD and jaw arc measurements from the NSW Shark Meshing Program jaw collection, an estimate of 2.8 m TL was established.

Basically we can conclude that the shark inflicted two bites : a complete jaw-arc (corresponding to W1) on the internal and front sides of the left leg, with a heavy loss of tissue which caused the death, and an arc from part of the jaw (corresponding to W2 and W3) on the back of that same leg, with almost no loss of tissue. Logically, the complete bite would be the first one inflicted, before the victim was aware of the shark, and the partial one resulting from a second attempt to bite, as the victim took evasive action.

3. Discussion

In terms of classification, this attack should be considered as an unprovoked attack, defined as incidents where an attack on a live human by a shark occurs in its natural habitat without human provocation of the shark (such as people spear-fishing, feeding sharks, etc.). This attack is one of 12 reported fatalities worldwide resulting from unprovoked attacks in 2011, the highest yearly total since 1993 (also 12).[8]

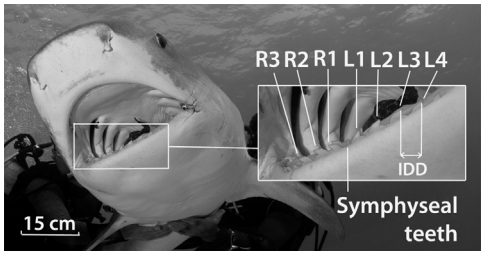

Fig. 4. Close up of central lower jaw of a tiger shark, *Galeocerdo cuvier*, showing the specific shape and position of teeth (L: left, R: right). The Inter-Dental Distance (IDD) is shown for the third to fourth lower left teeth (L3–L4). Note behind L1 and R1 the replacement teeth that can be responsible for parallel teeth impressions, such as in Fig. 2c'. Scale refers to main image (tiger shark).

The attack described here resulted in one major injury that resulted in rapid blood loss and induced hypotension. Combined with the fatal result, these features directly classify it at level 5 in the Shark Induced Trauma (SIT) Scale (a 1–5 scoring system based on the severity of the attack) introduced by Lentz et al.[9]

The analysis of wounds indicated a 2.8 m TL (est. length) tiger shark as responsible for this attack. We can consider it as a juvenile, as the average length at first maturity in male and female tiger sharks in the Central Pacific is greater than 3 m.[23] The estimates of TLs based on IDD and bite circumference vary by less than 5%, which lends confidence to the estimate of TL. Our finding is also consistent with the presence of tiger sharks in quite high densities in the coastal waters of New Caledonia.[6]

The activity of kitesurfing has been recorded relatively rarely in reports of shark incidents in the short period since this sport commenced. Surfboard-riding and other surf sports have been the most common activities involved in unprovoked shark attacks for the past decade (often >50% in a particular year). That was the case in 2012 with 60% of all cases worldwide (amongst 48 incidents). However, kitesurfing does not represent a high percentage of incidents amongst all surfing activities (including bodysurfing, windsurfing and bodyboard and surfboard users which represent >95% of the cases involving surf sports). Reported shark incidents with kitesurfers are: two in 2012 in Florida (USA), one in Papua New Guinea (amongst 41 incidents) in 2011 and two incidents each in Western Australia and Florida (amongst 38 incidents) in 2010. Apart from the current additional case from New Caledonia and the Florida case in 2010, all these incidents were non-fatal. The shark species involved was unknown in both cases of 2012, identified as a 2 m TL tiger shark in the 2011 Papua New Guinea case, and a bronze whaler (*Carcharhinus brachyurus*) in the 2010 Australian case.[8] These figures should be put into perspective with the total activity time and number of kite surfers compared to the number and total activity time of all other surf-users before concluding that kitesurfing is less risky than surfing with regards to shark attacks.

Apart from the lower number of practitioners of this sport, which could explain why kitesurfing accounts for significantly less shark attacks than other types of surfing sports, some features of this sport may be a factor in explaining the relative frequency of shark related incidents. Kitesurfing includes the use of a board moving along the water surface, but the sail contributes to much higher speeds than in surfboard-riding, in addition to multiple jumps (sometimes of several tens of meters). Those features might be significant limiting factors for a shark to attack a kitesurfer, compared to a surfer. However, when a kitesurfer does lose his board and is pulled by his sail along the surface, such as in the present case, with relatively high speed and intermittent touching-down on the surface, it could represent a strong feeding stimulus for a shark. Ritter and Levine (2004),[16] have argued that a general seal shape resemblance to surfers, as the reason for mistaken identity leading to white shark attack,[20] is insufficient to support such a misidentification. However the particular skimming motion of a kiteboard could be a possible factor under certain conditions. In the current case, a kitesurfer in the situation described above, could resemble a seabird moving over the surface, and could constitute a feeding stimulus for a tiger shark, triggering some form of active response.[1]

This hypothesis is consistent with the feeding behavior of tiger sharks in New Caledonia. The data presented by Rancurel and Intes,[14] Simpfendorfer,[18] Lowe et al.[10] and Simpfendorfer et al.[19] indicate that there are some differences in the tiger shark diet between these widely separated areas of the Indo-Pacific Ocean. Rancurel and Intes[14] showed that sea snakes and sea birds were the most commonly occurring prey items in New Caledonia, while teleost fishes were the prey with the most frequent occurrence in

Hawaii and Australia, with teleost fish, sea turtles and dugongs being the most frequent prey in Western Australia. The fact that tiger sharks in New Caledonia usually feed on seabirds might have been a facilitating factor for the attack of this kitesurfer in a reef passage, particularly where large birds, such as Boobies (*Sula* spp.), are quite common.

In conclusion, this attack could be summarized as an encounter between a large top predator with a feeding habit including surface prey and a large-bodied potential prey in a location strongly favored by sharks. The attack was a tragic event that should not however prevent us from acknowledging that fatal shark attacks on humans are overall extremely rare. However, in the context of the developing new water sports such as kitesurfing, more people will be using locations which were previously less-used such as reef passages with attractive waves, and where large sharks are in higher densities than in lagoonal coastal waters. Sea users should therefore understand that the level of risk of shark interactions increases with more frequent exposure in higher risk locations. These marine (recreational) ecosystems should then be regarded as the «wild», public safety should be better connected to personal behavior,[13] and sharks should not be seen as «alien agressors».

Ethical approval

It was not necessary.

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Conflict of interest

None.

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